TRANSITION FORMS IN CRINOIDS, AND DESCRIPTION OF FIVE NEW SPECIES.

BY CHARLES WACHSMUTH AND FRANK SPRINGER.

The subcarboniferous rocks of the Mississippi Valley have been divided, by geologists generally, into five divisions or groups, viz., the Kinderhook, Burlington, Keokuk, St. Louis, and Chester, which occur in the order named; the Kinderhook being the lowest and oldest. Full accounts of these formations may be found in the Reports of the Geological Surveys of Iowa and Illinois, to which we refer for detailed information. Of these groups, the Burlington and Keokuk limestones, extending in vertical range from the Oolite bed, which forms the summit of the Kinderhook, into the Geode bed, which apparently forms the boundary between the Keokuk and St. Louis limestones, are characterized in their fossil remains by a great predominance of crinoids. They are thereby somewhat conspicuously distinguished from the other members of the subcarboniferous sèries. It is to these crinoidal beds that our observations are at present limited. Their fossiliferous character is well known, and we may add that there is probably no region in the world which exhibits, within the same limited geographical extent, so great and uninterrupted a range of crinoidal deposits in geological succession, almost unaltered by disturbing forces, and which at the same time affords such a variety and abundance of well preserved specimens for accurate comparative study, as the vicinity of Burlington, Iowa, and the neighboring exposures of the Keokuk limestone, within a few miles to the south and southwest.

In 1860, in the Boston Journ. of Nat. Hist., vol. VII, No. ii, Dr. C. A. White gave a very interesting account of the geology of the Burlington region, and pointed out the relations, as then understood, of the formations here exposed, with each other, and with those occurring in the series above and below. It was shown that the Burlington limestone consists of two divisions, separated from each other by beds of silicious shales, chert and cherty limestones of varying thickness; that these divisions were characterized by striking differences in their fossil remains; that the upper division was succeeded in turn by an accumulation of sili-

cious beds, above which appeared the Keokuk limestone, differing from the Burlington beds in the specific characters of its fossils, as well as in lithological characters; that the three formations presented in their crinoidal remains three successive grades of development, those of the lower bed being generally of small size and delicacy of construction and ornament, those of the upper bed being of stronger construction and ruder form, while in the Keokuk they reach a culmination of rudeness and extravagance of form and size. He states that few, if any, species of these fossils are *common to both* beds of the Burlington limestone, and that it is hardly probable that any will be found common to the Burlington and Keokuk. The same writer, in the Geology of Iowa, 1870, vol. I, p. 202, says that the separation of the formations of the subcarboniferous group from each other is abrupt and distinctly defined; that the interposition of silicious beds constitutes paleontological boundaries between them; and that the change in the lithological character of each deposit toward the close of each epoch, seems to have had the effect to check, and finally to arrest the progress of those forms of life which previously existed in great profusion; and that with the resumption of calcareous deposits in the succeeding epoch, similar, if not identical forms, were introduced, which flourished and progressed until arrested again by similar deposits of silicious strata. And on page 203, speaking of the two divisions of the Burlington limestone, he says: "It seems that the accession of silicious material to the waters of that epoch resulted in, or at least was followed by, the extermination of all the species of crinoids then existing, and although they flourished in just as great profusion when the calcareous condition of the waters was restored, they were all of new species, these being all in turn exterminated by the accession of the silicious material which we find to mark the close of the full epoch of the Burlington limestone."

Such may be taken as the prevalent opinion among geologists and paleontologists as to the faunal independence of these three formations, although Dr. White does not deem it expedient to recognize *two distinct formations* in the Burlington beds, as proposed by Niles and Wachsmuth in Amer. Journ. Science, July, 1866, and as in practice is done by all the later paleontologists and collectors, it being shown by experience that in their organic remains, particularly crinoidal, the distinction between the two

Burlington beds is much more sharply marked and clearly defined than between the upper bed and the Keokuk limestone. The geologic independence of the two latter beds has been scrupulously regarded by paleontologists, and in no case within our knowledge has a single species of crinoid, out of the many hundreds described, been noted as occurring in both formations. Indeed, it would seem, judging from the descriptions, that the increase in new species would serve to confirm their separation. But an observer who is familiar with the stratigraphy, as well as the fauna of these rocks, throughout their whole vertical range, obtains an entirely different impression. Of the many distinguished paleontologists whose labors have contributed to our knowledge of the fauna of these beds, the majority were not themselves collectors, and they were therefore destitute of that personal familiarity with the mode of occurrence of these fossils, which is so important an aid to an accurate understanding of their relations. The material on which new species have been described has often been comparatively limited, and specific characters were readily distinguished in a single specimen which could not have been defined in a large series. There has also been some confusion, we believe, in regard to the actual horizon of the types of new species collected by various parties along the border land between the Burlington and Keokuk, some localities being referred to the one or the other, when in fact they belonged exclusively to neither. Furthermore, the two beds being thus for a long period considered as independent, it came to be regarded, as we have already seen, as an inflexible rule that their species must be distinct, as was also the case with the Burlington beds. Accordingly, new forms from the one or the other were brought within the rule, and specific distinctions were to some extent assumed to exist because of difference in geological horizon, thus illustrating the tendency to reason in a circle, into which even the most careful investigators, working in a single line, will occasionally fall.

We have been led by our researches to the conclusion that there is a much more intimate connection between these formations than has been generally supposed, and that the assumed extermination of organic forms at the close of each epoch, and the appearance in the next of new and distinct forms, cannot be reconciled with the facts which have been brought to light.

There is no doubt that the introduction of silicious matter in

great abundance into the waters was largely destructive of crinoidal life, and had also an important influence in producing the changes observed in the crinoids of the successive deposits. It seems, indeed, when there was too much of it, growth was arrested and life destroyed; but when it existed in the waters in moderate proportion, along with calcareous constituents, its presence was favorable to existence and individual growth. It is on the upper surface of cherty layers in the Burlington and Keokuk beds, that we find most of the "colonies" or local deposits of well-preserved specimens, and from the upper beds to and including the Keokuk, there is more or less of silicious matter in the matrix and in the fossils themselves. The strata which compose the beds of passage between the three beds are mostly impure cherty limestone, in which the proportions of silicious and calcareous constituents vary, and it is a fact that throughout these deposits, wherever a little bed of limestone appears, or the chert becomes rather calcareous in its composition, we find the remains of abundant crinoidal life, although mostly in imperfect preservation.

It thus seems that, notwithstanding the destruction caused by the silicious influx, some of the crinoids survived here and there, and struggled through until more favorable conditions again prevailed. In proof of this, we have the fact that throughout the cherty deposits between the Upper and Lower Burlington beds, we find more or less the remains of crinoids, usually in the form of casts and very imperfect, yet sufficiently distinct to be recognized as *Actinocrinus*, *Platycrinus*, etc. But it is in the beds of passage between the Burlington and Keokuk that we find the most satisfactory evidence of the persistence of crinoidal types, and these with the crinoids found therein form the basis of this paper.

The close of the Upper Burlington limestone (as heretofore considered) was marked by an extraordinary destruction of fishes, whose remains, in the form of teeth and spines, are found in the greatest profusion in a stratum two to ten inches in thickness, which occurs at the very top of the regular limestone beds. It is one of the best stratigraphic landmarks that we know in this formation, as it is found over a wide area in localities over a hundred miles apart, and always in the same position relative to the heavy limestone beds. It is succeeded immediately by cherty layers, sometimes in regular bands and sometimes in irregular

masses, with the interstices filled with a fine, brownish-red, silicious clay. These layers average about six to eight feet in total thickness, and above them there appears a stratum of whitish-gray crystalline limestone, from one to two feet thick, on the upper surface of which, and only on the surface, so far as observed, is found another deposit of fish remains. This is succeeded by two or three thinner layers of similar texture, separated by silicious shales and yellowish sand, and above these occur other irregular beds of argillaceous and cherty limestones of varying thickness, which pass gradually and imperceptibly into the bluish-gray limestones of the Keokuk proper. These deposits, from the first fish bed up to the Keokuk limestone, we designate, simply to save repeated explanations, as the "transition beds." They are found well exposed near Burlington, and at Augusta and Pleasant Grove, Iowa, both within twenty miles of Burlington, and at Sagetown and Nauvoo, Illinois, at all of which localities we have carefully studied them. At Nauvoo they are much thickened, and are seen above the town from the water's edge well up into the bluffs, which are capped by the Keokuk limestone, while in the extensive quarries below the town, only the Keokuk limestone has been exposed. A want of attention to these facts has caused some confusion as to the true horizon of the species described from that locality, all being referred to the Keokuk, whereas we have found at the upper locality true Burlington species, such as *Granatocrinus Sayi* and other well-marked species. The transition beds are more or less fossiliferous throughout, though the occurrence of the fossils is irregular and their preservation very variable. They exhibit in an irregular manner the lithologic characters of both formations, while the crinoidal remains which have been obtained from them show such an intermingling and blending of the Burlington and Keokuk species, that it is impossible to say where the one begins and the other ends. The majority of the crinoids found in them can neither be called Burlington nor Keokuk species, and may often be identified as either. They constitute a kind of intermediate type between them, and throw much light upon the growth of the individual and the development of species in course of time.

Our late investigations confirm the opinion, long held by us, that the Keokuk limestone and the Upper and Lower Burlington beds are only subdivisions of one geological formation, which might

appropriately be called the "crinoidal limestone." A considerable number of the fossils, under consideration herein, were obtained from a single layer of limited extent in the fish bed at the top of the Upper Burlington limestone. They are of comparatively few species, and those are extremely rare in other localities, but at this spot they seem to have flourished in extraordinary abundance. These specimens form so important a part of our material that, to avoid repeated allusions to the locality, we refer to them always as the "fish-bed fossils."

In the following pages we shall endeavor to illustrate in detail, with the excellent material at our command, largely collected with special reference to this subject, the transition between the forms of crinoids in the Upper Burlington and Keokuk beds, which we believe will possess geological as well as zoölogical interest.

It is to be regretted that greater attention has not been hitherto paid to the individual growth of crinoids. We have made collections expressly for the purpose of illustrating different stages of development, and have found it to be the rule, that in young crinoids, the basals are the most perfectly developed parts. They attain nearly their full size in young individuals, greater in proportion than the subradials and radials, which are comparatively early developed, and at a time when the interradial and anal plates have scarcely made their appearance. The latter develop the slowest, and in some genera increase continually both in size and number during the growth of the individual. We also find that abnormal growths, or sudden modifications of specific characters, almost always take place in the interradial and anal areas, the posterior rays, and consequently in the dome. Species have been multiplied by attaching too much importance to characters based on such modifications as the comparative size of the base, the number of interradial and anal plates, a more or less elongate form, etc., which we believe are due in many cases to individual growth, and which in species, when found in a later geological epoch, form mere variations of the same species, as will be proved most conclusively by the following genera.

1. BATOCRINUS, Casseday.

This genus is separated by Meek and Worthen into two sections, Ill. Geol. Rept., vol. V, p. 364, to which we refer for a full discussion of the generic characters and relations. In the first

section, *B. Christyi* is included, while *B. pyriformis* falls under the second. The two species form the types of two little groups of crinoids, which exhibit some very interesting features in connection with the succession of the crinoidal beds; both are very common and characteristic species of the Upper Burlington, and were described by Shumard in vol. II, Geol. Surv. Mo., with good figures, and figures of more perfect specimens are given in vol. V, Ills. Geol. Rept. Pl. V. There is a general difference in form and outline between the two species, but their chief distinction, and the one which produces apparently all the other constant differences, is that *B. pyriformis* has 20 arms, *one* from each opening; while *B. Christyi* has *two arms to each arm opening*, or 40 in all. This feature of *B. Christyi* has been for some time known, but hitherto the anatomical construction which produces it has not been understood, and this we are now enabled to explain. *B. Christyi*, in its typical form, has in each ray 3 primary, 2 secondary, and 2 tertiary radials, or radials of the third order, or as they are more commonly designated "brachials." The latter term is used for that series of radial plates within the body walls, which leads to an arm opening. The upper margin of the second or last of these brachial plates, is somewhat excavated, and in the rear of this cavity, the arm opening breaks through. In very well preserved specimens, when the arms have been removed, there may be seen upon the floor of this excavated margin, a narrow indented scar, extending from the arm opening directly outward. We have found resting upon this scar a very small, narrow, triangular or pentagonal plate, often, when the arms are attached, not visible from the outside. This is a rudimentary bifurcating plate, and corresponds to a third tertiary radial or brachial plate. Upon it, the arms divide, and just at the opening, on either side of it, is another small, short plate upon which the arms partly rest, the thin, small plates filling the excavated upper margin of the last brachial plate. Referring now to the dome, we find the double arm feature most beautifully indicated. Directly above each arm opening, there is a prominent interbrachial dome plate,[1] nearly round or elliptic in outline, and from

[1] For an account of these and other dome plates, as well as the construction of the dome of Paleozoic crinoids in general, see Amer. Journ. Scien. vol. XIV, Sept. 1877, p. 186.

low convex to high conical, sharp and projecting over the upper edge of the disk. This row of projecting dome plates is a very characteristic feature of this species, but is entirely wanting in *B. pyriformis*, its absence giving to the dome in that species its pyriform aspect and the upward tendency of the arm openings; while in *B. Christyi*, it gives to the arm openings a lateral direction, and to the disk its wheel-like appearance with its wide periphery standing about parallel to the vertical axis. Its peculiar office is well shown in one specimen, which has abnormally two extra brachial plates, and two arm openings instead of one in part of the ray. Here, a single interbrachial dome plate is situated between the arm openings instead of one over each, and the construction below leaves no doubt, that from these two openings *single* instead of double arms proceeded.

B. Christyi is described as having 7 anals and 4 interradials in 3 ranges each, and radials 3×2×2. Another species described by Meek and Worthen in vol. V, Ill. Geol. Rept. p. 372, under the name of *B. trochiscus*, belongs to this group, but has a more spreading disk, a more concave dome and a comparatively lower body than *B. Christyi;* it is described as having 12 anals and 6 interradials in 4 ranges each; radials 3×2×2 with an extra radial of the third order (or brachial plate) in some parts of the rays, and 1 or 2 interaxillary or intersupraradial pieces. The second radial of the third order is long, bent upward, and about the arm opening constructed exactly as in *B. Christyi.* The same interbrachial dome plate is found over each opening, very sharp and prominent, and although *B. trochiscus* has never been found with any portion of the arms attached, we feel entirely certain that when discovered, they will be found to be double from their origin.

Batocrinus planodiscus, Hall (sp.), (Supplem. to Iowa Rept. p. 45) is of the same type, and has a form similar to *B. trochiscus* with a much greater expansion of the disk, caused by an enormous development of the higher radial and interradial series. It has, according to diagram, 3 radials of the first order, 2 or 3 of the second, 2 or 3 of the third, and 1 or 2 of the fourth, or brachial pieces; 15 interradials in 9 ranges; 9 to 11 intersupraradials, 5 or 6 interaxillary plates between the series of radials of the third order, and it has 40 arm openings. The addition to the structure of *B. trochiscus* of another series of radials within the body walls,

and interaxillary plates between them, causes the arms, which, in that species, divided at the opening, to separate in *B. planodiscus* within the body, and to emerge simple from their origin. *B. Christyi* ranges through the Upper Burlington into the division beds. *B. trochiscus* is found only in the transition bed, while *B. planodiscus* is said to be from the Keokuk, although the type specimen came from Nauvoo, and there is the usual uncertainty in regard to its real horizon.

Now we have before us about 50 good specimens of *B. Christyi* from the Upper Burlington of various localities, all of which, by their peculiar aspect, are readily referred to this species. We find in them a wide variation in form, some being tall, with dome much elevated and rising uniformly from the margin of the brachial disk to the subcentral proboscis, others nearly turbinate below, with almost no expansion of the disk, and others having a low, broadly, and rapidly spreading calyx, with concave sides and a nearly flat summit. The proboscis is in small specimens, so far as observed, smooth, while in larger ones, it is rough, nodose, and spiniferous, the latter being generally the case in those found high up in the rock. Between these extremes there is every gradation. In these specimens, we find the following variations in body-structure: Anals, 5, 6, 7, 8, 9, 10, 11, and 21, in 3, 4, 5, and 6 ranges; interradials, 2, 3, 4, 5, and 6, in 2, 3, and 4 ranges, with variations of 2, 3, and 4 in different parts of the same individual. The radial series is $3 \times 2 \times 2$, except in one specimen (the one with 11 anals), which, on the inner branch of one posterior ray, has an additional bifurcation, giving 5 arm openings to that ray, or 21 to the specimen, one double arm being replaced by two simple ones, as in *B. planodiscus.* Three others show simple arms from two openings. Another specimen (with 21 anals) has in one branch of a ray the rudimentary bifurcating plate developed into a nearly full-sized bifurcating third brachial.

In ten specimens of *B. trochiscus* from various localities in the transition bed, we find the following variations in structure: anals, 7, 8, 12, and 13 in 3, 4, 5, and 6 ranges; interradials 4, 6, 7, and 8 in 3 and 5 ranges; interaxillary pieces (intersupraradials), 0 to 1 and 2; radials, $3 \times 2 \times 2$, with occasionally extra brachial bifurcating plates in some of the rays; giving in these parts the formula $3 \times 2 \times 3$. In some mature specimens there is in some places a narrow interbrachial plate inserted between the radials

of the third order, producing an expansion of the disk; and in one of them (evidently very mature), the interradial areas are much depressed, and the radial series elevated and rounded, giving to the calyx, as seen from below, a ten-rayed appearance. The proboscis, in specimens from the transition bed, is greatly developed, being very long, and its plates spiniferous.

We have never seen a specimen of *B. planodiscus*, but from the description and diagram, it is evident that this species has the same fundamental construction as the two preceding ones. The only important difference to be found is, in the additional bifurcation of the radial series within the body, and as a consequence of this structure, in the double number of arm openings. *B. Christyi* and *B. trochiscus*, though having 40 arms also, have but 20 arm openings, and the arms really branch after emerging from the body. In them, the small bifurcating plate which we have described, and upon which the arms divide, is evidently a rudimentary free radial, and the two plates beside it, which in *B. Christyi* were only arm plates, become developed in *B. planodiscus* into true radials and form a part of the body. That this is not a mere conjecture on our part is demonstrated by the individual growth of crinoids generally. The *young Strotocrinus* for instance, though having the same number of arms as the adult, has but 4 arm openings to each ray. The radials of the higher orders, which in adult specimens form a part of the body walls, are here still free arms, unsupported by any interradial or interaxillary pieces, which subsequently fill the spaces between them; but the number of arm openings of the nascent crinoid increases to the full number of arms in proportion to the increase of the upward growth of the body. This is exactly the case in *B. planodiscus*, and it will thus be seen that *B. Christyi* and *B. trochiscus* represent earlier stages of development, and that, as we have seen before, the two later forms differ from the older by those characters which appeared irregularly in *B. Christyi*, and became more fixed and general in the succeeding types.

B. pyriformis, whose most important distinction from *B. Christyi* has been mentioned, is described with 7 or 8 anals in 4 ranges; 5 or 6 interradials in 3 or 4 ranges; radials, $3 \times 2 \times 1$ (see vol. V, Ill. Geol. Rept. p. 375, where Meek and Worthen give a revised description). It ranges through the Upper Burlington

into the transition beds, where the *B. Nashvillæ* form predominates.

B. Nashvillæ, Troost, from the Keokuk limestone, is of the same type, but is larger, and its body and dome plates are more nodose, the interradial areas constricted, so that the body is divided into lobes. It is described by Hall in vol. I, pt. ii, Iowa Geol. Rept. p. 609, with 8 or 9 anals, 5 to 10 interradials, and an intersupraradial plate between the radials of the second order in every ray; radials, $3 \times 2 \times 1$; arms, 20.

B. Nashvillæ var. subtractus, White, was described (Proceed. Bost. Soc. Nat. Hist. 1862, p. 16) as agreeing with the last species, except that it generally lacked the intersupra-radial plate, this being found in one ray only. It was said to occur in the Upper Burlington.

In upwards of 40 good specimens of *B. pyriformis* examined, we find a great variety in form. In some, the body expands gradually and uniformly from the base to the arm bases, giving a turbinated outline below; while in others, it remains of nearly uniform size to the top of the second radials, when it suddenly and rapidly expands; the radials of the second order and brachials being in a plane nearly at right angles to the vertical axis. In some specimens, two-thirds of the body is below the arm bases, and in others, scarcely one-third. In some, the brachial disk is continuous; in others, the interradial areas are somewhat depressed, and the body shows a tendency to become lobed. Between these extremes there is almost every shade of difference. In the structure of the body we find the following variations: anals, 6, 7, 8, 9, and 11, in 4 and 5 ranges; interradials, 3, 4, 5, 6, and 7, in 2, 3, 4, and 5 ranges, with differences in the same individual. There are no intersupraradials in any of them. In general, the specimens from the upper part of the beds are larger, more developed proportionally in the dome, and exhibit the greatest tendency to become lobed.

The form which Dr. White has described under *B. Nashvillæ var. subtractus*, is found at the very top of the Upper Burlington, and also in the transition bed. It agrees closely with *B. pyriformis*, but is always more or less lobed, and this is the principal distinction between the two forms. In 13 specimens, all from the above horizon, we find the following differences in structure: Anals 9, 10, and 11 in 4, 5, and 6 ranges, interradials, 5, 6, 7, 8, and 9

in 3, 4, and 5 ranges with variations in the same individual. As to the intersupraradials, upon which White founded his variety, we find in some specimens none, and in others one in 1, 3, 4, and even 5 rays respectively, while all our Keokuk species of *B. Nashvillæ proper*, have an intersupraradial in every ray. But the presence and constancy of those plates, is evidently a natural consequence of the greater size of the Keokuk form, and hence of no specific value.

In *B. pyriformis*, the proboscis is long, rather strong, with moderately convex plates. In the *B. Nashvillæ from transition beds*, the dome is prolonged into a proboscis over five times the height of the calyx, the plates of which are convex to slightly spiniferous. In the *B. Nashvillæ of Keokuk*, the proboscis is similarly elongated, but stronger, composed of very nodose plates, and about midway to its summit it is encircled by a row of five very strong spines, nearly an inch long.

We find that the modifications, thus observed in the successive forms of these two types, as they appear in the rocks, have taken place in exactly those parts of the crinoid which are changed by growth; that the prevailing features of the later species are those which in the Burlington types were irregularly developed during the life of the individual; and that the order in which these modifications appeared, corresponds very closely with the succession of changes from youth to maturity.

2. ERETMOCRINUS.

Lyon and Casseday, Am. Journ. Sci. 1859, proposed the above generic name for a type of Crinoids, principally distinguished by the flattening of the arms in their upper parts. Meek and Worthen, Ill. Geol. Rept. vol. V, p. 367, placed it under *Batocrinus* as a subgenus, and made interesting observations on the genus and its associate forms. We have never seen a specimen of Lyon and Casseday's typical species, and are unable to undertake a discussion of these somewhat complicated generic relations. We are inclined to the opinion, however, that at present the characters of *Batocrinus* and *Eretmocrinus*, are not so clearly defined as could be desired. Under existing circumstances, we prefer to leave *Eretmocrinus* where its authors placed it.

Among the fish-bed fossils, some of the most striking examples belong to this type. They exhibit the peculiar arm structure in

a remarkable degree, while they possess a special interest in connection with similar forms from other localities. The specimens here occurring belong to a single type. They are characterized by a low, broadly calyculate body, with basal plates in some cases, thickened into a slight rim at the margin, and in others projecting far out around the column in a tripartite disk. Three brachial plates, in succession, rest above the secondary (or supra) radials, with an extra set of radials of the third order, in part of those rays which have five arms. Dome much elevated, pyriform or hemispheric; its plates strongly nodose or subspiniferous. The surface of the body below the arms is ornamented by rugose ridges, which extend along the middle of the radial plates, and follow the branches to the arm bases, the latter being separated from each other by indented sutures. These ridges are in some specimens low and obscure; prominent and angular in others. The arms are strong, rather narrow as if laterally compressed, and nearly angular on the outside for about one-fourth their length. They are there very suddenly flattened, spread out laterally, and become broad and spatulate, remaining thick and heavy in the middle, and growing thin toward the edges. Their breadth at the widest point is about half an inch on an average, they taper very gradually toward the tips, the length being, in mature specimens, about four inches. They are composed of a double series of interlocking joints, which are very short in the lower, and longer in the spatulate portion of the arms. The former are triangular in their transverse section, the short base being on the under or ventral side of the arm, the longer sides being on the outer or dorsal margin and slightly convex, while they join in the middle by their shorter sides. The under faces of the joints make obtuse re-entering angles with each other, in which the ambulacral furrow is situated. In the flattened portion of the arms, the joints have a triangular cross section, but the position of the triangles is so changed that they join in the middle by their bases, the shorter sides are on the flat, dorsal surface of the arm, while the under margins, on the ventral side, which are slightly concave, are the longer sides. The angles opposite the longer sides are a little greater than right angles, so that when closely fitting together by their inner faces, the flattened halves or wings of the arms, are lifted up at their margins, and angularly depressed in the middle. It is a remarkable and interesting fact that the halves of the flat-

tened arms, not only join with each other at the middle by interlocking angles, but have similar angles at their thin, lateral edges, which exactly correspond with the angles in the margins of the adjoining arms. Thus the edges of the arms could be united by closely fitting sutures into a continuous and impenetrable wall, and form an arched dome over the space above the arm bases. Indeed, we always find the arms folded inward at their extremities, no matter in what shape the specimens are crushed.

We have, from other localities in the Upper Burlington limestone, specimens which are perfectly smooth below the arm bases, but which in size, shape, and structure of the arms, agree with the fish-bed specimens very closely. Among a good number of the latter, we find some with 20 arms, some with 21, and some with 22, the difference being always in the posterior rays, as the others have uniformly 4 arms each. The variation in the surface markings bears no relation to that in the number of arms, for we find the smooth specimens with 20 and 21 arms, and the ornamental ones with 20, 21, and 22, and we are therefore led to believe that all the specimens under consideration belong to a single species.

Meek and Worthen, in vol. V, Ill. Geol. Rept. pl. x. Fig. 5, have given, under the name of *Eretmocrinus remibrachiatus*, Hall, a figure of a specimen which was obtained at the same locality, though not in immediate association with our present collection of fish-bed fossils. It gives a good idea of the form under consideration, except that in perfect specimens, the flattened portion of the arms is at least twice as long as seen in the figure. It has three brachial plates in the body, and twenty arms. But that specimen, like those before us, clearly does not belong to *E. remibrachiatus*, described by Hall in his Preliminary Notices, 1861, p. 11, under *Actinocrinus*. His species had, according to the description, no body plates above the secondary (or supra) radials, and had 16 arms which were rounded below and expanded above the middle, which is a totally different thing from our forms. We have not been able to exactly identify Hall's species, but we have several specimens of a form with but two supraradials in some parts of the rays, and a brachial plate in others. It has 14 arms which are very strong, rounded below and flattened above, and we think it belongs to *E. remibrachiatus*,

the type of which may have had, abnormally, an additional arm in each posterior ray.

Hall described and figured in the Iowa Rept. pt. ii. p. 615, pl. xv. Fig. 7, under the name *Actinocrinus ramulosus*, a specimen which in most respects shows a very near approach to the fish-bed forms. It is referred to the Keokuk limestone, but as it came from Nauvoo, we are left in doubt as to its actual horizon. It may have come from the transition beds, for we have from corresponding high beds at Augusta, Iowa, where these beds are extensively exposed, a specimen which seems to be almost an exact duplicate of Hall's type as figured. The ridges are composed of series of prominent tubercles in the centre of each plate in the radial and brachial series, and there are also, between the ridges, much smaller tubercles distributed around the margin of the anal and interradial plates. It has, moreover, 5 arms in each posterior ray, or 22 in all, and we have no doubt but that Hall's specimen would have shown the same number, if that portion of the fossil had been preserved. The arms are unknown. A comparison of our specimen of *A. ramulosus*, with the fish-bed forms of *Eretmocrinus* shows that they are most intimately related. The only difference, we can perceive, is the rather greater size and more elaborate ornamentation of the *A. ramulosus*, being difference in degree only, and not in kind.

We are thus brought to the conclusion that the type we have described, is not specifically distinct from *A. ramulosus*, which thus includes forms ranging from the Upper Burlington, through the transition beds, and possibly into the Keokuk. Those who attach great importance to surface markings or minute anatomical differences, such as one or two arms more or less, would perhaps find in these specimens the types of several species. But with the fossils before us, sufficient in number and preservation for thorough study and comparison, and exhibiting the intermingling of characters we have noted, we can but regard them as varieties of one and the same specific form which will be, of course, *Eretmocrinus ramulosus*, Hall (sp.).

In this type we have, again, a most interesting illustration of the gradual shading of Burlington into Keokuk forms, and the intimate relations of the crinoidal remains of the two formations.

3. AGARICOCRINUS, Troost.

On bringing together a large number of good specimens of *Agaricocrinus* from the Upper Burlington, transition and Keokuk beds from various localities, apparently belonging to several species, we found a satisfactory separation into species according to the descriptions impossible. We therefore thought to ascertain their relations by a comparison of the specimens before us, without regard to specific names or geological horizon. The comparative simplicity of construction and absence of ornamentation in this genus renders such an investigation more easy than in many other groups. To this end, we noted for each specimen, separately, the characters which in the descriptions have heretofore been considered of specific importance, viz., the form of the dome, of the basal concavity, and of the anal area; the shape and position of the second and third radial plates; the form and proportions of the interradials, and the character of the interradial area in the dome; the number of arms; and in addition to these, and not heretofore specially noted, the disposition of the apical plates of the dome. Tabulating these data independently of the specimens, we found that they fell naturally into two groups. The first of these is characterized by having the apical plates of the dome separated from each other by small intercalated plates; the central apical plate being tuberculiform and very much larger than its associates or any of the dome plates; the dome pyramidal, anal area flat, and the opening lateral; three arms to each posterior ray; second radial higher than wide; first interradial short, basal concavity small, involving the lower part of the third radial, which is convex. The second group is distinguished by having the apical dome plates connected except at the anal side, the central one not greatly conspicuous above the others; the dome hemispherical; the anal area elevated, rounded, or protuberant, with the opening directed upward; the second radials nearly always quadrangular and wider than high. Within this group are forms with 2 arms to each ray, with 3 in one posterior ray, with 3 in each posterior ray, with 3 in one posterior ray and 4 in the other, with 4 in each posterior ray, the other rays in all cases, save one, having 2, with long and narrow first interradials, and with short and wide ones; with basal concavity very shallow, not involving any part of the third radials, and deep, entirely including them.

The first of these groups is sharply characterized, and is the well-known species *A. Wortheni*, Hall. The second is of the type *A. Americanus*, Roemer, but includes the features of *A. bullatus* and *A. excavatus*, Hall, and *A. nodosus*, M. and W., and a new form not heretofore noticed, having four arms in each posterior ray; but the combination of these characters was so perplexing that the identification of the species was wholly unsatisfactory. Upon arranging the specimens, however, according to the most general modifications, such as the greater or less elevation of the anal area and the number of arms, we found that they arranged themselves into a series, in which, while varying irregularly in the minor characters observed, the forms shaded gradually from one into the others, beginning with those having two arms to the ray and greatly protruding anal area, and ending in those with four arms to each posterior ray and a wide flat anal area. In these respects the succession was nearly regular, but no other characters were coincident with them, and, in other respects, there was no uniformity or constancy whatever. It was now found that the specimens had also *arranged themselves* according to their geological horizons, beginning with two-armed forms in the Upper Burlington, and extending regularly through the transition beds with two and three arms, to the four-armed forms in the highest part of the Keokuk.

In this study which we have described thus in detail, to show that there is nothing arbitrary or theoretical in the result announced, we used about thirty well-preserved specimens, besides the description of the types, and we were forced to the conclusion that, in the second group, it is not possible to draw lines which shall separate it into species, but that these forms are only variations of a single species, of which *A. Americanus* is the type, and under which *A. bullatus*, *A. excavatus*, and *A. nodosus* must fall. *A. Wortheni* occurs, so far as observed, only in the upper part of the Keokuk, and is very characteristic of it. We have from the Upper Burlington a single specimen, evidently very mature, in which the apical dome plates are crowded apart by small plates, and which has short interradials, but which in every other respect agrees with the two-armed form of *A. Americanus*. We also observed in a very large specimen of *A. Wortheni*, which is somewhat injured in the rays, an arrangement of dome plates, which leads us

to think it probable that this form will be found with four arms to all the rays.

The Burlington species of *Agaricocrinus* are comparatively small, increasing in size in the upper bed; the transition bed fossils are larger still, and in the Keokuk there are found those ponderous, huge forms which are so characteristic of that horizon, and of which *A. Wortheni* is the extreme. With these extravagant forms the genus becomes extinct, and we meet it no more above the Keokuk beds.

4. ACTINOCRINUS.

The *lobed* Actinocrinus which Meek and Worthen considered to be the true type of the genus, is numerously represented in the crinoidal limestones, and a large number of species have been described from the Upper Burlington and Keokuk beds. The type of the genus is a form subglobose to turbinate below the brachial plane, very slightly convex to pyramidal above the arms, the interradial spaces contracted, the radial areas prolonged and extended outward about at right angles to the vertical axis, and formed into lobes which increase in width as they recede from the body; thus giving to the fossil when seen from above or below, a pentapetalous aspect.

Its leading species in the Upper Burlington beds are *A. multiradiatus*, Shum. and *A. verrucosus*, Hall, both figured on Plate 10 of the Iowa Geol. Rept. The former is characterized by a very low, flat dome, with the interradial areas greatly constricted and excavated ; the latter by an elevated dome and a greater development of the interradial dome plates, which extend down between the lobes and form a low rim connecting them. The former has 30 arms, the latter 40, the arms of both remaining simple throughout. In this genus, unless the arms themselves are preserved, it is very difficult to tell their number, for the long projecting lobes are almost always broken away with the arms. In large collections from the Burlington limestone, of specimens otherwise well preserved, it is exceedingly rare to find one in which the brachial plates are preserved to the bases of all the arms. They are generally broken away just above the first bifurcation in the ray, and the number of arms appears less than it really is. This was the case with *A. multiradiatus*, which is represented in the Iowa Report as having two arms to the ray ; when in fact it has six as

large collections prove. In the Keokuk beds the genus attains its greatest development in size and extravagance in features. It is represented by a large number of described species, of which the leading types are *A. Lowei*, *A. pernodosus*, and *A. jugosus*, Hall, and the species of *A. Humboldti* and *A. Agassizi*, Troost. Most of the Keokuk species were apparently described from specimens more or less imperfect in the brachial part of the lobes, so that very little reliance can be placed in the arm formulæ stated, and no information is given in the descriptions as to the nature of the arms in the different species.

The Burlington specimens exhibit much variation in proportions and ornamentation, and while they are generally of small size and neat sculpturing, we find occasionally a mature individual which, with most of the features of its associates, is much larger in size and is marked with that roughness of habit and rudeness of form, so prevalent in the Keokuk. The Keokuk species named are all very large, uncouth forms, with extreme rugosity of surface, the latter reaches its extreme in *A. Agassizi* and *A. pernodosus*, while in *A. Lowei*, the contraction of the interradial spaces above the arm bases is so great, that almost the entire dome is included in the five lobes. Specimens from this formation, preserving the arms, are exceedingly rare, and our Keokuk material generally is too limited for a detailed comparison of forms. But we have a specimen of the *A. verrucosus* type, apparently *A. pernodosus* or *A. jugosus*, which shows the arms to be very large and strong, and six to the ray; while another, which we suppose to be *A. Agassizi* of Troost's catalogue, has apparently 20 arms, which are the most ponderous that we have seen in any crinoid. Two specimens from the Keokuk of Indiana, received from Dr. H. S. Harrod, of Canton, which we consider to be young and old individuals of *A. Lowei*, have eight primary arms on the posterior rays, and six in the others; they possess the very peculiar feature not hitherto noticed, that the inner arms of each ray, instead of being simple throughout, *bifurcate* about midway, giving 10 and 12 arms to the ray at the extremities.

In the transition beds, there occur certain forms, represented by many specimens, in which the characteristic features of the Burlington and Keokuk species are united. They shade into *A. multiradiatus* on the one hand, and into *A. Lowei* on the other, by such easy gradations that specific distinctions are impossible.

It is probable that *A. brontes* and *A. unicarinatus*, Hall, which were described from Nauvoo, and which we were unable to identify, never seeing an authentic specimen, belong to these same intermediate forms. Among specimens from the transition beds, we have found one in which, as if foreshadowing the peculiar arm features of *A. Lowei*, some of the arms were *simple*, *while others divide* an inch above their bases into two branches. This type also having reached its culmination in the Keokuk beds, becomes here extinct.

5. PLATYCRINUS, Miller.

Mr. F. B. Meek, in Hayden's Reps. U.S. Geol. Surv. of the Territories, for 1871, p. 373, proposed the name *Eucladocrinus* as a subgenus for the reception of a type of *Platycrinus*, in which the radial series are extended into long, free tubes, bearing the true arms along their sides. Some lately acquired material from the crinoidal beds, and especially the fish bed, enables us to add something to present knowledge of this form. The type under consideration has exactly the body structure of *Platycrinus* up to the third radials. It includes both the low, broad cup-shaped, and the elongate form of calyx. But instead of giving off the arms in clusters from the third radial as usual in *Platycrinus*, it has the radial series of the body, both dorsal and ventral, enormously extended in the form of tubular free rays, from which the arms spring alternately on either side throughout their length. It bears the same relations to the typical *Platycrinus*, that the form, described as *Steganocrinus* by M. and W. in vol. II, Ill. Geol. Rept. p. 195, does to the *typical Actinocrinus*, it being sometimes impossible, with our present knowledge, to determine to which genus the specimen belongs when the arms are removed.[1]

The value of these differences in arm arrangement as to generic relations is as yet an open question; but we have found that the structural difference between the two forms is not by any means so great as first impressions would indicate. The free rays of *Steganocrinus* are actually nothing but extreme developments of the lobes of *Actinocrinus multiradiatus* or *A. Lowei*, and in like

[1] A similar variation in the arms is observed in *Hexacrinus*, those of *H. brevis*, Goldfuss, being similar in type to the earlier forms of *Platycrinus*, while *H. limbatus*, Müller, has arms of different type, somewhat like *Eucladocrinus*, but more like *Barycrinus*.

manner the radial extensions of *Eucladocrinus* are produced by a multiplication of the orders of radials in the body of *Platycrinus*, as proved in the most satisfactory manner by our *Platycrinus prænuntius* herein described, in which the intermediate stage is shown. We doubt whether there is any generic distinction between the two forms, but in the unsettled state of our science upon this question, it is probably best, and may facilitate the search for a natural classification to recognize subgeneric groups however artificial they may be.

This group includes, so far as known, our *Eucladocrinus millebrachiatus*, *Platycrinus pleurovimenus*, White, besides *Pl. Montanaensis*, Meek.[1]

It ranges in our rocks from the Upper Burlington through the transition beds and into the Keokuk limestone.

Another species, somewhat similar to *E. millebrachiatus*, both in ornamentation and form of the calyx, but having the arms of true *Platycrinus*, ranges through the crinoidal beds and is called *Pl. sculptus* when found in the Lower Burlington, *Pl. glyptus* in the Upper, and *Pl. Saffordi* when found at Keokuk localities. We can see no difference between them, and it is an interesting confirmation of our opinion, that we have before us a specimen from the Burlington limestone at Quincy, kindly loaned to us by Prof. Worthen from the Nat. Hist. Museum of Illinois, which is exactly like some of our Lower and Upper bed specimens, and which was identified by Prof. Hall, who described all three species, as *Pl. Saffordi*. It is also worthy of note for our present investigations that this species being a simple and typical form of the genus, survives through all three divisions of the crinoidal limestone, while on the other hand, so far as observed, the extravagant forms soon become extinct.

[1] Hall's species, *Pl. nodobrachiatus*, Iowa Rept. p. 542, seems at a casual glance to have a somewhat similar arrangement of the arms. But his description was undoubtedly made from a young specimen, and a comparison of a large number of very young specimens of *Platycrinus*, in some of which the arms are only sprouting, as it were, shows that the arrangement seen in his diagram, is that of the nascent *Platycrinus* generally, and that the little side appendages are pinnules and not arms. The arm joints, in the young of this genus, are mostly single, the tips only being formed of a double series of interlocking joints, which in the adult prevail down to the bifurcation of the arms.

Eucladocrinus millebrachiatus, n. sp.

Column very large and long, twisted, composed of joints which increase in thickness as they recede from the body. The faces of the joints are eccentric elliptic, the rim beveled to an edge, sometimes sharp and sometimes obtuse, from which project, rather irregularly, small tooth-like spines. Each joint is twisted so that the long axes of the reverse faces make a considerable angle with each other, while the articulation on the long diameters imparts a rapid twist to the whole stem, and permits motion in all directions. The articulating processes run lengthwise of the face of the joint, and consist of a strong ridge along the middle, with another on either side near the periphery, and curving like it. There are deep depressions on either side of the median elevation, probably filled by interarticulary substance. Perforation of the column round and extremely minute, barely large enough for the insertion of a fine needle point.

Body, exclusive of free rays, of medium to large size, cup-shaped to elongate hemispheric. Basal and first radial plates thin; basal disk low, about one-third the height of the body. Facet for attachment of the column slightly indented, and surrounded by a low lamellose ridge, or by a row of small tubercles. Surface of basal plates marked by rows of small nodes and rugose ridges, arranged parallel to the margins and radiating to the angles, the same ornamentation extending upward on the first radials. Edges of basals obtusely bevelled. There is considerable diversity in the surface sculpturing, it being obscure on small specimens, conspicuous on large individuals. First radials higher than wide, their sides about parallel, margins not bevelled, but forming close sutures with adjacent plates; gibbous in the middle and swelling toward the margin of the second radials. Articulating facet large, broad, semicircular, occupying one-third to one-half the height, and one-half to one third the width of the plate, facing outward nearly parallel to the vertical axis. Anal plate about equal in size to the interradials, inflated above, and forming a part of the flattened dome. The anal opening situated at its upper margin.

Beyond the first radials, the rays extend out horizontally, both on the dorsal and ventral side, and are produced into long free tubular, arm-like appendages, which are really extensions of the body in the radial series. They bifurcate on the second radial into two branches, which do not immediately diverge, but remain

united by their inner sides as far as the middle of the third radial plate, beyond which they become free, and continue so to their extremities. Hence, there are two free branches to each ray, or ten in all, each of which bears the true arms on either side in alternate succession. The branches are of about uniform size for half their length, after which they taper gradually and apparently terminate in a true arm. A tubular passage, arched over by the extensions of the dome, runs the entire length of the free rays. The tubes of the two branches, after uniting on the inside of the second radial, connect with the central visceral cavity.

Second radials very short, broad and deep, filling the entire surface of the articulating scar, rounded below, curved at the sides to meet the dome plates, their transverse outline about semicircular, dorsal aspect obtusely pentagonal, though actually heptagonal. The lateral extremities of this plate, like those of the succeeding radials, have angular faces interlocking with corresponding faces of small plates, which fill the interbrachial areas on the ventral side of the rays. The upper equal faces of the plate slope at a very obtuse angle, and bear two plates in succession, which are radials of the second order. The first of these is short, hexagonal, its long margins about parallel, its outer lateral margin notched by a small channel, which penetrates through the plate to the tubular cavity within. The inner lateral margins of this and the next interlock with those of corresponding plates in the other branch of the ray, the salient angles of one meeting the sutures of the other. The second radial of this order is almost quadrangular, though actually pentangular, much narrower than the adjoining ones, and sustains on its outer sloping face the base of an arm. It is slightly wedge-form, its greater height being on the inner margin, and this causes the division of the ray, which takes place near the top of this plate.

The plates throughout the entire length of the free rays form an indefinite number of successive orders of radials of two each, the second of which is a cuneiform bifurcating plate, sustaining on its longer upper face the plates of the next order of radials, and on its very short outer sloping face, in connection with the still shorter outer face of the first plate of the next series, the brachial pieces which form the beginning of the arms. The brachial pieces, or first pair of arm-joints, are rather deeply set into the ray, and while they rest chiefly upon the cuneate second

radial of each series and the outer face of the succeeding plate, they also abut against the plate above and below. In one very large specimen, in part of the ray near the body, they are imbedded still deeper, so that they touch five plates of the ray, as is the case in *E. pleurovimenus*, but at a greater distance from the body they abut only against four, as is the general rule.

The arms are long, rather strong, gently tapering, directed along the rays toward the extremities; composed of a double series of rather short interlocking plates, every alternate one on either side giving rise to a long, slender, single-jointed pinnule. The arms are given off from each pair of plates in the free rays, alternately on each side, thus giving an arm for every two plates throughout their length. In one of our specimens, of medium size, there are about 30 arms to one branch, but the extremity is not preserved, and we have reason to think they averaged 10 more, which would give 80 to the ray, or 400 in all. In some of the larger specimens, the number was doubtless much greater, and probably in some cases approached 500.

Dome flat, composed of comparatively large plates, the apical and radial dome plates being at their middle part abruptly elevated into papillate nodes with a roughened or wrinkled surface. The plates of the interradial areas, of which there are but few, are smooth. At the place where the rays emerge from the inner body, directly over the second primary radial, there is a large dome plate marking the incipient bifurcation of the ray, with several small ones below, succeeded by two rows of very large, extremely prominent plates like those of the dome, but much more conspicuous and with coarser surface markings. The latter are placed along the ventral side of the ray, and alternately on either side, so that one plate is always situated over the base of an arm, and by counting them the number of arms can be determined as readily as from the radial plates on the dorsal side. The spaces between these brachial dome plates are occupied by smaller, flat, rounded, or subspiniferous plates, irregularly arranged. The arrangement of the vault pieces of the rays is such that they could not have opened, and hence the passage within was always tubular and never an open canal. The radial appendages have a tendency to bend downward, leaving the ventral surface exposed.

We have noted the presence of a small channel at the lateral extremity of the first radial of the second order, and will now add

that this forms the passage of a good-sized pore. Similar pores, pierced through at the edge of the plate, and inclosed by the abutting margin of an adjacent plate, are found on each side of the free rays near the base of every arm. They communicate with the tubular passage, and have about the same direction as the arm furrows One pore penetrates every first brachial piece on each side of the arm-base, another enters at the outer lateral edge of the first radial of each order, a third one occurs at the edge of the second radials ; but toward the upper or thinner part of the rays, we found only two pores between each pair of arms in place of three as described.[1]

[1] The presence of the pores in the sides of the radial appendages is such a notable feature in the form under consideration, that interest is naturally awakened as to their probable functions, and this the more since similar pores have been observed by us in several other genera. They are very conspicuous in *Batocrinus*, where they are arranged in ten pairs, five radial and five interradial, each pair is situated between the adjacent arms, and they connect through the body walls with the inner cavity. They are found also in *Actinocrinus* and *Strotocrinus*, in the free arm bearing rays of *Steganocrinus*, within the false arms of *Ollacrinus*, and pores are found in the ventral sac or so-called inflated proboscis of some of the *Cyathocrinidæ*. If now we compare the position of these openings with the so-called ovarian openings of the Blastoids and the pectinated rhombs of the Cystidians, which are considered by some authors to be ovarian, by others respiratory organs, the question is forcibly suggested whether these may not have had the same functions, perhaps serving as a madreporic apparatus for the introduction of water to the body. Such organ has never been noted in Paleocrinoids, and yet, must have existed in them somewhere. In some genera, the pores in the body walls were evidently absent, but we have observed in this connection that in those genera the *column* is not only very large, but the tubular cavity within is of extreme size, and follows with its ramifications the numerous branches and roots into which those columns divide. Their cavity is peculiarly constructed, generally pentapetalous in form, and its inner walls throughout built up of thin laminated plates with innumerable slits, punctures, pores, grooves, ridges, and other processes, through which a communication with the surrounding water was easily effected. Such complicated structure shows that the column must have performed a vastly more important office in the animal economy than that of an attachment to the sea bottom, and may have had here the additional functions of those of the pores, especially as we find that in every genus in which pores have been observed in the body walls, the perforation in the column is very small and shows no signs of a structure as above described. We call attention to these facts at present in the hope that they may lead to observations on the subject elsewhere, and we hope hereafter to give it a more detailed investigation.

In the investigation of this species we have made use of a magnificent series of specimens from the fish bed, found within a few feet of each other. There are nine individuals in good preservation presenting to view almost every aspect of the fossil, they represent different stages of growth, and show the gradations from small to large individuals. We have also before us a specimen from the division bed at Nauvoo and three from the Keokuk limestone. The latter are considerably larger than the fish-bed specimens, but exhibit otherwise, in the parts preserved, no essential difference. Only a portion of the rays is preserved on one of the Keokuk specimens but sufficient to show that it had the same arm structure. Until discovery of more perfect specimens shall prove the existence of more important differences than yet observed, we can only regard the Keokuk form as belonging to the same species, with the tendency to variation generally observed in Keokuk representations of Burlington types.

This species is distinguished from *E. pleurovimenus* by the low discoid calyx, the flat concave base, the massive body plates, the deep sutures, the more robust and rapidly tapering radial appendages of that species. In four specimens, we find that the free rays are always folded inward upon the ventral side instead of hanging down as in our species. It has about the same number of arms as ours, and either of them with their ten long rays fully extended, and the hundreds of arms stretching outward must have presented a very striking appearance.

Locality and Position.—Near Burlington, Iowa; transition bed between the Burlington and Keokuk limestone. Collections of C. Wachsmuth and Frank Springer.

Platycrinus prænuntius, n. sp.

Column large, twisted, and constructed as in *E. millebrachiatus*. Body rather large, low, broadly cup-shaped or discoid. Basal and radial plates heavy; basal disk deeply and abruptly excavated below, so that four or five joints of the column are inside the plane of its outer rim. Basal plates elevated near their margins into a thickened, rugose rim, which is also found near the lower margin of the first radials. All the plates are broadly and deeply bevelled on their margins. First radials one-half wider than high, their lower projecting margins overhanging below the plane of the base, so that the body rests on these margins when

placed upon a level surface. Articulating facet prominent, much elevated by the thickening of the plate; broad, semicircular, occupying about one-third the width and height of the first radial, its surface about parallel with the plane of the plate, which makes an angle of about 45° with the vertical axis. Anal plate a little larger than the inter-radials, supporting on its upper face a series of small dome plates, above which is the anal aperture, situated very low and opening laterally.

The radial areas are produced into free appendages, approaching the structure of *Eucladocrinus.* They are large, strong, and broadly rounded below, spreading out about horizontally and folding upward on the ventral side. They bifurcate on the second radial, but remain joined by their inner sides to the top of the second plate above it, where they diverge and become free. The branches diminish in size very rapidly, giving off arms alternately on either side to about the twelfth plate, where each terminates in a bifurcating plate, from whose equal upper faces two true arms diverge. The surface of the plates is irregularly elevated and rounded, and the sutures are slightly sinuous, giving to the rays a wrinkled or corrugated appearance.

Second radial short, broad, filling the articulating faces, pentagonal in outline, bearing upon its upper obtusely-sloping faces the radials of the second order, two in succession, whose inner edges join, but do not interlock, the sutures in the two series coinciding. The first radial of the second order is about quadrangular, its upper and lower margins flexuous. The second is much narrower and is a bifurcating plate, whose longer upper face bears the radials of the next order, while its short, acutely-sloping outer lateral face sustains the lower margin of the first and largest brachial piece. The second radial of the next order gives rise to an arm on the opposite side, and so on alternately to the end of the ray. There are about six pairs of radials of as many orders, each of which represents an arm, and the last pair two arms; thus giving off normally seven arms to each branch, fourteen to the ray, and seventy in all. The first pair of brachial pieces are large, of unequal size, and imbedded in the ray so that they abut against four of the radial plates. Arms comparatively long and heavy, composed of a double series of interlocking plates with a furrow on the ventral side connecting with the tubular cavity of the ray, and apparently bearing pinnules in the usual way.

Dome elevated, hemispheric, composed of large tumid plates, of which the apical and interradial ones are the most prominent, the radial area in the vault being composed of a double series of smaller plates, which extend out along the ventral side of the rays as continuations of the dome.

This species, in its body structure, is most closely related to *E. pleurovimenus*, having a similar low discoid form and heavy plates, but it can be easily distinguished by the extremely deep excavation of the base below, the prominent ridges at the margins of the basal and first radial plates, the extreme depth and width of the bevelings at the sutures, the elevation of the articulating faces, and by the very distinct arm structure. It resembles *P. tuberosus*, Hall, in its discoid dorsal cup, but in that species the calyx is much lower, the arm-bases being in the plane of the base. The deep and acute beveling of the margins of the plates in our species gives it a sharp, angular appearance not visible in any other species.

Position and Locality.—Upper Burlington division of the crinoidal limestone; subcarb., Burlington, Iowa. Collections of Fr. Springer and James Love, Esq.

Platycrinus prænuntius, as stated before, represents the transition form between the *typical Platycrinus* and *Eucladocrinus*, the latter being the extreme wing of the genus. A comparison of the species of *Platycrinus* occurring in the Upper and Lower Burlington beds, gives further interesting results concerning the history of the genus. In all the species from the Lower bed the arms, both of the discoid and of the elongate form, divide upon a triangular or pentangular bifurcating plate having equal sloping faces, and the two halves of the rays are free above the second radial, or become so at the first radial of the second order; while in almost every species from the Upper bed the arms branch off alternately from the smaller sloping face of a more or less cuneate plate (similar to *P. prænuntius*); and while we find on the former not over four arms to each half ray, with abnormally a fifth one, there are species in the Upper bed with seven, eight, and nine arms to each half, or eighteen to the ray. There are before us some most interesting specimens of a form from that horizon, perhaps of *P. Halli*, Shum., but more probably, at least if Meek and Worthen's identification of that species in vol. V, Ill. Geol. Rep. p. 454, is correct, of an undescribed type which, in the form of the

body and the general plan of its radial construction, is so intimately related to our *E. millebrachiatus* (as *P. prænuntius* to *E. pleurovimenus*) that one is forcibly struck with the idea that the former may possibly represent a younger stage of the latter. That this, however, is not the fact, is proved beyond doubt by a number of specimens of each species and of different size, which show the greatest constancy in their respective characters; and, as the two forms occur in a distinct horizon, we are compelled to regard it as not individual growth, but as a more mature development of the genus.

6. ICHTHYOCRINUS, Conrad.

In investigating some specimens, apparently of this genus, of a new form and unusual size from the fish bed, we encountered much difficulty in determining their generic relations, and were accordingly led to an examination of the entire literature of this and its allied genera, *Taxocrinus* and *Forbesiocrinus*. Meek and Worthen, in vol. II, Ill. Geol. Rep. p. 269, have discussed the relations of the two last-named genera, and have furnished good reasons for considering *Forbesiocrinus* to be only a subgenus of *Taxocrinus*. The generic formula, which includes both, is shown to be: 3 basals, which are sometimes rudimentary, 5 subradials, and 3 or 4×5 radials. It thus appears that the only difference between the two forms is in the interradial and anal areas, *Taxocrinus* being either without plates in these spaces or having but 1 to 3, and *Forbesiocrinus* having from 7 to 30, or more. *Taxocrinus* ranges from the Upper Silurian up, while *Forbesiocrinus* is mainly confined to the Subcarboniferous. The genus *Ichthyocrinus* was established by Conrad in 1842 without generic diagnosis. According to Bronn, Klassen des Thierreichs, vol. II. p. 231, it has 5 basals, 3×5 radials, and no anals or interradials. Hall, in vol. II, Paleont. N. Y. p. 195, and in the Iowa Rep. vol. I, pt. ii. p. 557, describes the genus as having a round, smooth, and slender column, 5 basal plates, 3×5 radials, the basals being small, and there being sometimes three other rudimentary plates within the 5 basals. Five American species are known of which Hall described *I. lævis*, *I. Burlingtonensis*, *I. subangulatus*, and *I. tiaræformis* (Troost), and Winchell and Marcy *I. corbis*. Of these *I. tiaræformis* is said to have 4 radials in the anterior ray, and *I. corbis* 2×5 radials, but all agree with the generic formula in having

no interradials or anals. Specimens of *I. Burlingtonensis* before us distinctly show the presence of 3 rudimentary basals mentioned by Hall as probably of generic importance, and this would make the formula: basals, 3; subradials, 5; radials, 3×5; thus agreeing precisely with *Taxocrinus* and *Forbesiocrinus*, except in the absence of anals and interradials.

The discovery of our new species *I. nobilis* brings fresh confusion to the subject, and obliterates at once this apparently satisfactory distinction. In this species, in young and mature individuals, we have 1 to 3 to 5 interradials, 1 to 2 interaxillary plates, and 3 to 4, mostly 4, primary radials with a wide variation in the radials of the second and third orders, sometimes in the same individual. On the other hand, Hall describes, in the Journ Bost. Soc. Nat. Hist. 1861, p. 261, under *Forbesiocrinus Thiemei*, another Burlington form, of which the typical specimen (without doubt adult) had neither anal nor interradial plates. Thus showing in a most satisfactory manner, that the interradials may be present or absent in either type. In Hall's species, the radials are 3×5, which increase in size upward, the second order of radials, and sometimes partly the third order, leaning against those of the adjacent rays. This species agrees up to the top of the secondary radials most remarkably with *Ichthyocrinus*, and only differs in the upper series of radials, or free arms, which are rounded on the back in place of being flat as in that genus. That we have since found other specimens with 0 to 1 and 3 interradials in one or more areas, and even 5 or more in its representative from the Upper Burlington bed, cannot diminish the weight of our argument; it rather serves to prove more conclusively, that the presence or absence of these plates is of but little value even as a specific character. Hence there remains no distinction as to the body structure between the three genera. The Burlington forms of *Ichthyocrinus* are readily recognized by the level plates and uniform curvature of the body, the disposition of the arms which rest closely against each other and infold at their tips, the waving sutures, and rapidly increasing width of the primary and secondary radials. In *I. laevis*, Hall, the plates are obtusely angulated, and in *I. subangulatus* the surface of the radials is elevated in the centre, and in *I. corbis* the margins of the radials are straight, while *Forbesiocrinus* and *Taxocrinus* have undulating sutures to a greater or less extent. Thus, the only constant character is

the closely joining and infolding arms of *Ichthyocrinus*. Under this state of facts it seems clearly impossible to longer maintain generic distinctions between the three forms. As *Ichthyocrinus* is the oldest name it must take precedence, and *Taxocrinus* and *Forbesiocrinus* be considered, at the most, as subgenera under it. But whether even this separation can be upheld seems to us doubtful. That in *Ichthyocrinus* the arms join and infold, that the basals are rudimentary, only visible from the inside, that in *Taxocrinus* and *Forbesiocrinus* those plates are more developed, appearing externally, are no *bona fide* features upon which to found subgenera, and yet, they seem, with our present knowledge to be the only constant characters for separation; in all others we find such an easy gradation from one species to another, such an intermingling of characters among the three types, that it appears almost impossible to draw a line where the one genus shall begin and the other end.

Ichthyocrinus nobilis, n. sp.

Column round, comparatively small, and with small spiny processes in the periphery of every alternate joint. Central perforation moderately large with pentapetalous section.

Calyx large, forming with the closely folded arms a smooth, subglobose or ovoid body. Basals not visible; the five subradials seen only at the angles. Primary radials, four to the ray, two and a half times as wide as high; widest at the upper margin. In large individuals, they increase rather slowly in width to the fourth plate, the rays being separated by large interradial spaces, but in smaller specimens, with only few interradials, the increase is very rapid. Secondary radials 3 to 4, varying more or less in the same individual, the largest having 4 in 9 branches and 3 in the other branch, one specimen of medium size has 4 in 7 branches, and 3 in 3; a young example has 3 in 5 branches, 4 in 2, and the others not visible. Those plates increase in width very rapidly, the upper ones being 4 to 5 times as wide as high, so that above the interradial spaces, the sides of the rays join again. In the next or third order of radials, there is variation of 3, 5, 8, and 9 plates in the ramifications in the same individual. In all our specimens, there is at least one more bifurcation beyond this, apparently throughout the rays, giving at least 40 arms, but in the largest individual there is still another on the outer tertiary ramifications of each half of the ray, while the inner ones remain simple, thus

giving 12 arms to each full ray or 60 in all. All the radial and arm plates have a very irregular outline, the bifurcating plates being pentangular, the others more or less quadrangular, with additional small angular faces. The upper and lower margins of the plates are strongly undulated and deeply depressed in the middle somewhat as in *Forbesiocrinus*, and showing in the second series of radials very obscure patelloid plates. The undulating feature extends even to many of the lateral margins; the tendency throughout the whole body being to curved lines. The surface of all the plates is smooth and level with the others, except the gentle curvature which accommodates them to the general sphericity of the body,—that is to say, the surface of the body is uninterrupted by any elevations or surface angularity of the plates. The arms are flat, comparatively broad, and lie close together, touching at their sides, the lines of junction being straight. The plates both of arms and body are very thick and heavy; those of the arms have on their inner or ventral side a deep furrow with another smaller and shallower groove on either side. Between the rays, there is a set of interradials, extending upward in a wedge-like arrangement from a little above the level of the primary radials, filling a considerable space. There are in full grown specimens from 3 to 5 interradials of rather large size, but we find in one apparently very young individual only a single plate and only one interradial space. Between the first branches of the rays, there are 1 to 2 interaxillary plates which are narrow and elongate. These plates, as a transverse section of one of the rays shows, are cuneate or pyramidal, their apices directed outward and wedged between the radials; and in this case, the interaxillary, though large and massive, had not penetrated through the wall, none being visible from the outside.

This species is readily distinguished from all described forms of the type by its 4 primary radials and its interradial plates. From *Taxocrinus* and *Forbesiocrinus* it differs in its subglobose form, uniform surface, the flatness and close infolding of the arms.

Position and Locality.—From the fish bed at the top of the Upper Burlington division of the crinoidal limestone; subcarb., near Burlington, Iowa. Collection of C. Wachsmuth.

7. CYATHOCRINUS, Miller.

This genus is remarkable for the persistence which some of its forms maintain throughout the crinoidal formations. A careful examination of the prevalent Burlington forms (both from description and numerous specimens), which we were induced to make in connection with some unique forms from the fish bed, gave interesting results. The common species described, and most numerously represented in all the collections that have ever been made at Burlington, are *C. Iowensis*, O. and Sh., *C. divaricatus*, and *C. malvaceus*, Hall, always considered lower bed species, and *C. viminalis*, Hall, from the upper bed. The identification of these species in large collections has always been attended with difficulty, except those specimens of this type found in the upper bed, which were promptly referred to *C. viminalis*, it being taken for granted, in pursuance of common understanding which had acquired the force of law, that the same species could not be found in both beds.

If the descriptions of these four species be considered together, it will be found that but one species is represented, with slight variations in the form and proportions of the plates. According to the description, they all have small, subglobose bodies, with basal plates minute to moderately large; subradials proportionally large, equilateral to wider than high, and obtusely angular to tumid, and gibbous; radials about equal to, or smaller than the subradials; articulating scar impressed, small to moderately large; arms divaricating to strongly diverging; surface granulose to granulose-striate. An examination of over a hundred specimens of this type, most of them having the arms preserved, has disclosed such a promiscuous combination of all these characters, as to render specific separations entirely out of the question, and has satisfied us that the differences noticed in describing isolated specimens are individual, and the result of different stages of growth of the one species, *C. Iowensis*. The type of *C. divaricatus* was no doubt the younger stage in which the basal portions were most prominent, and *C. malvaceus*, a mature individual in which the greater development of the subradials left the basals proportionally small. Between supposed typical specimens of *C. Iowensis* from the lower bed, and of *C. viminalis*, no difference can be pointed out in the body, and the only character which we can dis-

cover to mark the forms from the two beds is, that in the Upper bed specimens, the arms generally taper slightly more than in those from the Lower bed. The similarity, indeed identity, in all other respects, is so striking, that we see no other course than to consider them all as one and the same species, which would fall under the older name *C. Iowensis.* We have been forced to this conclusion only after the most faithful investigation of the abundant material at our command, and in which the collections from the different horizons are authentic. But our difficulties do not end here. We find this same form occurring not unfrequently in the typical Keokuk localities, and indicating not only a striking persistence of type throughout the whole crinoidal formation, but similarity of specific characters quite remarkable. It is described by Prof. Hall as *C. parvibrachiatus*, and, in the specific characters named by him, it agrees with the Burlington type in every respect except the more rapidly diminishing size of the arms. Numerous specimens from various localities show that this feature is quite variable, and one series of 18 individuals, from near Bonaparte, Iowa, collected there in a thin layer not over two feet square, and preserving the arms, shows the same intermingling of minor characters and variety of size as is found in the Burlington forms. One of these specimens, placed beside a similar individual from the Lower Burlington, presents to the eye scarcely a point of difference. On an average, however, we find the Keokuk specimens to be a little larger, their arms stronger in the lower parts, and more rapidly tapering than in those from Burlington, and hence we do not feel at present authorized (nor do we wish to do so when it can possibly be avoided) to interfere with the specific name. Some other species of *Cyathocrinus* in the Keokuk limestone tend toward more robust forms and heavier arms, and among the fish-bed fossils we have discovered several forms departing from the characteristic types in the same direction, of which we describe two new species.

Cyathocrinus barydactylus, n. sp.

Column very large, larger than in any known species of the genus, its projecting joints more or less serrated, central perforation of moderate size, and obscurely pentapetalous. Body of medium size, bell-shaped, turbinate below, abruptly spreading in the first radials, greatly constricted at the dome. Diameter at arm bases about equal to height, though less in smaller specimens.

Internal cavity egg-shaped, smallest below. Basals large and prominent, more than two-thirds visible beyond the column, the visible part pentangular, directed upward, and forming a cup whose sides make a very small angle with the vertical axis. Subradials large, higher than wide, four hexagonal and one heptagonal, their surfaces slightly convex. First radials about as wide as high, greatly thickened toward the margin of the articulating facet, and their upper margins very strongly incurved, so that the diameter of the dome is about equal to that of the internal cavity at the middle of the subradials. Anal plate about one-fourth the size of the first radials, higher than wide, and supporting the plates of a lateral upright proboscis. Body plates thick and heavy, especially the first radials, marked by a coarse irregular rugose ornamentation, which is least observed in the first radials. The sutures are rather deeply marked. Articulating facet flat to slightly concave, much elevated, facing outward, about parallel with the vertical axis, and occupying about two-thirds the area of the plate. Its outline is elliptic, notched on the ventral side by the arm furrow. Succeeding radials free, broadly and deeply rounded, two-thirds as wide as the first radials, forming very strong rays of nearly uniform diameter, one bifurcating on the fourth free radial and two on the second, the others not being seen, exhibiting in this respect an irregularity common to the genus. The plates below the bifurcation are quadrangular as viewed from the outside, and of about equal size, being a little over half as long as the first radials. The bifurcating plates are pentangular, the upper margins being equal and nearly at right angles, sustaining two equal branches of half the size of the free radials. These bifurcate again on the second or third plate, and there are two or more bifurcations above, apparently all from the second or third plate. The most remarkable feature of the species is the rapid diminution of the size of the arms, which are comparatively shorter than in any other known species of this genus. They are composed of single joints, constricted in the middle, expanding at their upper margins, and are without pinnules. The form and size of the free rays, and the sudden shrinking in the arms, gives to the form an entirely unique appearance not unlike that of *Onychocrinus*, and the height from the base to the top of the primary radials is more than half that of the entire fossil, excluding the column. The arms are provided at their ventral

side with a comparatively small, though deep furrow of tripartite form, which extends throughout the arms. The contraction of the body at the summit is very similar to that in *Poteriocrinus* (?) *geometricus*, Goldfuss (*Sphaerocrinus*, Roemer), of the Eifel, as illlustrated by Schultze in his monograph Pl. V, Fig. 6. The thickness of the first and the succeeding radial plates in this and the succeeding species might suggest a reference to *Barycrinus*, but the arm structure and column at once proves it to be *Cyathocrinus.*

This species differs so entirely from all other described Burlington forms, that comparison is unnecessary, and the only species occurring elsewhere to our knowledge, which at all approach it, are from the Keokuk limestone; as for instance *C. multibrachiatus* from Crawfordsville, Ind., which has also a turbinate body, but is otherwise quite distinct.

Locality and position same as last. Collections of C. Wachsmuth and Frank Springer.

Cyathocrinus Gilesii, n. sp.

Column comparatively small, projecting joints rounded on the edges, central perforation small, obscurely pentapetalous Body depressed, cup-shaped, two-thirds as high as wide, though a little more elongate in young specimens; slightly expanded at the middle of first radials, and so deeply and abruptly constricted at the dome, that the diameter at the upper margin of the plates, in mature specimens, is about the same as that at the outer angle of the basal plates, thus making the internal cavity nearly spherical.

Basals comparatively small, about one-half their size exposed beyond the column, forming a nearly flat disk, with the points of the plates inflected upward at a slight angle with the plane of the base. In young specimens, these plates are more prominent and bend upward at a greater angle. Subradials large, about as wide as high, and of the usual form, strongly convex to tumid. First radials very large, more than half the height of the calyx, elevated around the margins of the facet, and their upper margins abruptly and deeply incurved. There is only one anal plate in line with the first radials, and it is of about one-fourth their size; the succeeding plates form a part of the proboscis which is placed laterally with an upward direction. Body plates comparatively thin, excavated in the inside. Surface destitute of ornamentation.

Articulating facet moderately elevated, flat to concave, and about parallel to the vertical axis; its outline circular and notched by the arm furrow. Succeeding radials form free rays, which are cylindrical, thick and strong, the plates having the same transverse outline as the facet. The free radials are irregular in number, and like the arm plates constricted in the middle, as in *C. barydactylus*, with the exception that in our present species the second radial is much shorter. Sometimes, especially when the facet is quite concave, the latter plate is wedge-form with its thin edge directed outward, so that the plate itself is only visible near the ventral side of the ray. The arm furrows converge at the centre of the dome. Five rather prominent so called consolidating plates of deltoid form, placed at the sutures, and resting in the thin incurved margin of two adjoining first radial plates, connect with each other by lateral extensions beneath the furrow, leaving an opening in the centre. Both central opening and furrows were undoubtedly covered with small plates, which have not been preserved in our specimens, but we found one in which a part of the arm furrow is covered by interlocking plates, similar to the arm covering of *C. Iowensis*, described by C. Wachsmuth (Am. Journ. Sci. vol. XIV, Sept. 1877, p. 183).

This species has some features in common with the preceding one, and had we but a single specimen we might well consider it an abnormal variation from that type. But having before us several specimens of each form, of various sizes, we find its leading characters so constant that we are compelled to regard it as distinct. The size of the column, the form and size of the basals, the tumid subradials, the low cup-shaped body, the thinner plates, and the short second radials are features by which it can be readily identified. It bears some resemblance to *C. rotundatus*, Hall, of the Burlington, and *C. parvibrachiatus*, Hall, of the Keokuk bed; but is distinct from both in the size and shape of the first and of the free radials, while it differs, like *C. barydactylus*, from all other known species in its proportions, half the entire height of the fossil above the column being embraced between the base and the first bifurcation.

The specific designation is in memory of J. W. Giles, Esq., of Burlington, Iowa, who first developed the locality of these fossils, and then lost his life while engaged in geological explorations.

Position and locality same as *C. barydactylus*. Collections of C. Wachsmuth and James Love, Esq.

8 **OLLACRINUS, Cumberland.**

The form which we include under the above generic name, has been described by Phillips as *Gilbertsocrinus*, by Hall as *Trematocrinus*, and by Lyon and Cassidy as *Goniasteroidocrinus*. Meek and Worthen, in vol. II, Ill. Geol. Report, p. 217, have given a very full review of the literature of the subject, together with an able discussion of the characters of this interesting genus, which have been, in some respects, entirely misunderstood by earlier writers. The true nature of the foramina in the upper part of the radial series was shown to be that of arm openings; while the interradial appendages, which were described as arms by Hall and others, were demonstrated to be not arms, but entirely independent organs, supposed to be connected with reproduction or respiration. To their very instructive observations, to which we refer as the basis of our remarks, we are enabled, by the possession of more perfect material, to add some interesting facts. With Meek and Worthen we cannot agree, however, in regard to the nomenclature of the genus. Cumberland, in 1826, proposed the name *Ollacrinus* for this type, and gave very good figures by which it may be recognized with much greater facility, indeed, than by Phillips's generic diagnosis and descriptions. According to the rules of the British Association, Cumberland's name is, without doubt, entitled to priority. Neither can we see any sufficient reason for separating the genus into two sections, as proposed by those authors. Authentic specimens of the three European species, *Gilbertsocrinus calcaratus*, *G. bursa*, *G. mammilaris*, Phill., show that the pseudo-brachial appendages occupy about the same relative position to the arm-openings as in the American species, and that they are not situated over the interbrachial or radial spaces, but over the interradial areas. We are inclined to believe that the misconception of the nature of the pseudo-brachial appendages led to a misunderstanding of the arrangement of the body plates, and that the interradial series has been mistaken for the radial one. There is some variation in American specimens as to the position of the arm openings dependent upon the direction of the arms. In the specimens in which Meek and Worthen found the true arms preserved, they

were pendent, and from this fact it was stated that in this genus the arms were always pendent, and not erect as in the allied *Rhodocrinus*. We find this true in the species named, as also in *O. typus*, Hall, of the Upper Burlington; but in *O. tuberculosus* the arms are erect and fold upward over the dome; and, while in the latter species the arm furrows and pinnules are placed like those in other crinoids on the upper or ventral side, they are, in *O. typus*, upon the under or apparently dorsal side. The same is the case in *O. tuberosus*, L. and C., from Crawfordsville. This peculiar structure is easily explained if we consider that the pendent position of the arms in these species is due, not to a forcible bending out of their normal attitude, but to the peculiar construction of the brachial parts, which directs them downward and makes this their natural position; and, while it appears as if the arm structure was entirely reversed in these two types, this is really not the case, the furrow is still on the ventral side, but the arms have rotated on their axes so as to bring it on the inner side when hanging down.

We have before us some twenty-five specimens of this genus, mostly of *O. typus* and *O. tuberculosus*, about half of them having the false arms, and eight the true arms preserved also. The two species are very satisfactorily separated by characters, the most of which were not disclosed to the learned paleontologist who described them, by the material at his command. We therefore give briefly their additional distinctive characters.

Ollacrinus typus, Hall (sp).

Interradials and anals varying from 7 and 11 in young specimens to 14 and 17 in mature individuals. Pseudo-brachial appendages very large, long, and pendent, spreading to nearly twice the diameter of the dome, tapering gradually, each joint having on the upper side a row of bead-like tubercles, which vary in number and size in different individuals. True arms (as observed in five specimens) pendent, long, and recumbent, directed downward from the openings, which originate in rather large, deep cavities under the overhanging margins of the bases of the false arms. The arms bifurcate on the second short, free, brachial plate, and again, on the third or fifth plate above, after which they are simple and composed of a double series of small thin interlocking plates.[1]

[1] *O. tuberosus*, from Crawfordsville, Indiana, also has a double series of plates in the arms, instead of a single, as described by Meek and Worthen.

The ambulacral furrow is on the under side of the arms, and bears pinnules which point downward. *Trematocrinus papillatus*, Hall, seems to be identical with *O. typus*, for we find both the papillate nodes and long spines on specimens which undoubtedly belong to the latter.

Ollacrinus tuberculosus, Hall (sp).

Anals and interradials about thirteen in adult specimens. Pseudo-brachial appendages without ornamentation, short, small, rapidly tapering to a point. The true arms, as observed in three specimens, are directed upward and folded over the dome, with the ambulacral furrow and pinnules on the inner side, as usual in crinoids. Arm openings in small cavities on either side the base of the false arms. Arms composed of a double series of plates and arranged as in *O. typus*. There are apparently four arms to the ray, although in one instance a fifth one was observed. Body plates large, tuberculiform, and not spiniferous. This, as well as all other Burlington species, has two secondary radials (supra-radials), and not three as stated.

In the fish-bed locality the *O. typus* existed in vast numbers, but, although the fragmentary remains of upwards of a hundred individuals were traced there, only a few were found in fair preservation. They were mostly of larger size and more robust form than specimens from other localities; the tubercles on the joints of the false arms were fewer in number and larger, while the lower body plates were less prominently spiniferous.

Ollacrinus robustus, Hall (sp.), from Keokuk, seems to be larger and more robust than the Burlington species, but the structure of the false arms is not described, and we have never seen an authentic specimen of that species.

In *Ollacrinus tuberosus*, L. & C. (sp.), the only species of the genus described from the Keokuk limestone of Crawfordsville, Indiana, there is a marked distinction from the prevalent Burlington types in the false arms which are composed at their bases of four ranges of plates above and two below. It is therefore an extremely interesting fact to find that in *O. obovatus*, M. and W. (sp.), which occurs only at the very uppermost part of the Upper Burlington beds, there are also four ranges of plates in the upper side of the false arms, which is the case in no other Burlington species. This is one of the rarest fossils of our rocks, only three specimens having ever been found, to our knowledge; and in this

isolated crinoid we have another instructive illustration of the structural transitions by which types are modified in the successive epochs.

9. DORYCRINUS, etc.

The history of this genus in the Crinoidal limestone is of great interest. The species of the Lower Burlington are small, and all have a single spine which is on the apex of the dome. *D. unicornis*, O. and Sh., is occasionally found with three, in which case the nodes of the radial dome plates in the posterior rays are prolonged into small spines—an abnormity upon which Hall founded his *Actinocrinus tricornis.* This latter species cannot be upheld, as we find those plates in every stage of development from nodose to spiniferous; sometimes only one plate is prolonged, the other one being normal. Yet, this variation is exceedingly interesting as showing the first step toward a modification which, in the Upper Burlington and Keokuk beds becomes a constant character; in the species of those two beds the first radial dome plates, not only of the posterior ray but of every ray, are prolonged into long spines. The *lower bed Dorycrini* have heavy arms, flattened toward the tips, and closely resembling those of some species which Meek and Worthen refer to *Eretmocrinus*, but differing from them in being double from their origin instead of single, as in *Eretmocrinus.*

In the *upper bed* species, with the exception of *D. parvus*, O. and Sh, which has altogether the character of those from the lower bed, the body is larger, but the arms comparatively more slender, shorter, and less flattened, while the central apical plate and the five first radial dome-plates are produced into long spines, as already stated. In the *transition beds*, the specimens attain a still larger size in *D. intermedius*, Meek and Worthen. The dorsal side of the calyx, which in all Burlington species is higher, or at least as high, as the ventral, here becomes proportionally lower, while the opposite part (above the arms) predominates; and in the Keokuk species the latter is by far the larger portion of the body.

In the *Keokuk beds* the extreme is reached. The body and body-plates are massive, the spines which, in the Burlington species, increase with the progress in geological time, here attain the immense length of 4 or 5 inches, and in one species bear

secondary spines. This species, *D. Gouldi*, with its extraordinary feature of spines on spines, was exceedingly short-lived, and disappears already in the lower part of the Keokuk, where it first occurs.

A very similar case is that of *Strotocrinus*, Meek and Worthen (Ill. Geol. Rep. vol. II, p. 181), which, in its typical form, began in the Upper Burlington, though its ancestry is very readily traced in certain Lower Burlington forms. It apparently found favorable conditions in the upper beds, for several species at once developed extreme proportions, the rim at the brachial disk extending in some specimens nearly an inch and a half from the body all around. These large forms are a very common and characteristic fossil in the middle part of the upper bed, but above that they are scarcely ever seen. The smaller types are found somewhat higher, but the genus is extinguished in this formation, not a single specimen having ever been found in the Keokuk.

Barycrinus has a similar history. Commencing in the Lower Burlington in species of moderate size, it becomes in the Keokuk, through transition forms, which are with great difficulty separated into varieties, one of the leading genera, and attains in *B. magister*, Hall (sp.) and *B. magnificus*, M. and W., a gigantic size. These large forms disappear with the Keokuk, and the isolated species found in later formations are small in size and of rare occurrence.

Amphoracrinus appears in the Lower Burlington, where it at once develops extraordinary features in the dome, which is extended into a large, but short proboscis, surrounded by very strong spines, which sometimes give off four or five branches as large as the primary spine. It reaches in America its climax in the Lower Burlington, and no trace of it is found in any succeeding formation.

Megistocrinus, Owen and Shumard, after attaining an immense size, perishes in the Upper Burlington. *Zeacrinus*, on the other hand, like *Cyathocrinus*, in its more prevalent small forms, ranges almost unchanged through all the crinoidal beds, it being very difficult to distinguish those from a different horizon by definite characters. It even continues to flourish in somewhat similar forms in the later formations.

It seems, from the foregoing observations, to be a general rule in the crinoids of these formations, that extravagant forms and

rank developments in structure are not perpetuated, and that types mostly cease to exist when they reach a culmination in anatomical features.

We have also seen that, although crinoidal life existed abundantly throughout the formations under consideration, a large proportion of the genera did not survive them; that where extinctions of generic types occurred, it was generally upon their attaining a climax in growth; that the extinguishment of specific forms was not coincident with the close of the respective epochs of limestone deposits, but that most of the changes were made by a series of slow and gradual modifications of specific characters, which correspond in a striking manner with the changes in individual life by growth; that the silicious deposits, while accompanied by great changes in the crinoidal forms, instead of marking sharp distinctions between the limestone formations, exhibit the gradations by which they are connected; that the smaller and less conspicuous forms were generally persistent, and ranged through the whole crinoidal formations with comparatively little change.

We have by no means given all the data at our command bearing on the subject, and our knowledge is necessarily limited. Much further research is required before a thorough understanding of the questions herein discussed can be expected. We are satisfied that a comparative study of the other organic remains, so abundant in these rocks, especially the Fishes, Brachiopods, and Bryozoa, would yield facts similar to those observed in the crinoids. But, however imperfect our investigations, we believe the evidence tends strongly to prove that the distinctions said to exist between these three limestone beds are, to a great extent, arbitrary; that the relations between their crinoidal fauna are most intimate; and that there is good reason for believing that they all belong to one great crinoidal epoch, and should be classed accordingly by geologists.